



УДК 517.925

ANALYSIS OF MODES FOR HYDRAULIC PULSE SYSTEM WITH
NONLINEAR SPRING ELEMENT

V.G. Gorodetskyi

Ph.D., Assoc. Prof.

Igor Sikorsky Kyiv Polytechnic Institute

Abstract. We investigated the dynamic characteristics of a single-mass model of a hydraulic pulse system using the example of a hydraulic hammer with real parameters. The model is a non-autonomous system of ordinary differential equations with a sinusoidal external action in one of the equations. The study revealed the dependence of the modes of operation of the hammer on the values of the parameters of its mathematical model.

Keywords: single-mass model, system of differential equations, external action, dissipation coefficient, periodic function

Aim. The construction of adequate models of hydro-impulse systems contributes to their improvement, the choice of optimal modes of operation, more efficient operation [1]. When designing such systems, it is important to forecast the nature of the oscillation processes, which in turn affects equipment characteristics such as efficiency, noise and vibration, and more.

Methods. At the initial stages of research and design, single-mass models may be sufficiently effective for some types of equipment [2, 3]. In this work, the influence of model parameters in the form of a non-autonomous system of ordinary differential equations on the dynamic characteristics of hydro-impulse systems is investigated.

The single-mass hydraulic hammer model proposed in [2] was used as the object of identification:

$$m\ddot{x} + b\dot{x} + C(x)x = F(t). \quad (1)$$

In (1) m - the combined mass of the hammer, b - the dissipation coefficient, $C(x)$ - the nonlinear stiffness, $F(t)$ - the force of the external action. We consider the case where $C(x) = c_0 + c_1x^2$, where c_0, c_1 are constant, and $F(t) = P \sin(\omega t + \varphi_0)$, where P - the amplitude, ω - the circular frequency of oscillations, φ_0 - the initial phase. Parameters close to real values were adopted, namely: $m = 65$, $b = 520$, $c_0 = 1,5 \cdot 10^4$, $c_1 = 1,5 \cdot 10^7$, $P = 3,595 \cdot 10^4$, $\omega = 31,416$, $\varphi_0 = 0$. All these parameters have system SI units.

The equation (1) was transformed to system:

$$\begin{cases} \dot{x}_1 = x_2, \\ \dot{x}_2 = -b_m x_2 - c_{0m} x_1 - c_{1m} x_1^3 + P_m \sin(\omega t + \varphi_0), \end{cases} \quad (2)$$

where $x_1 = x$, $b_m = b/m$, $c_{0m} = c_0/m$, $c_{1m} = c_1/m$, $P_m = P/m$. The system (2) was solved by the 4th-order Runge-Kutta method at a time interval of 5 s after the transition period with a step $5 \cdot 10^{-6}$ s. The solutions of system (2) are presented in Fig. 1, and its phase portrait is shown in Fig. 2.

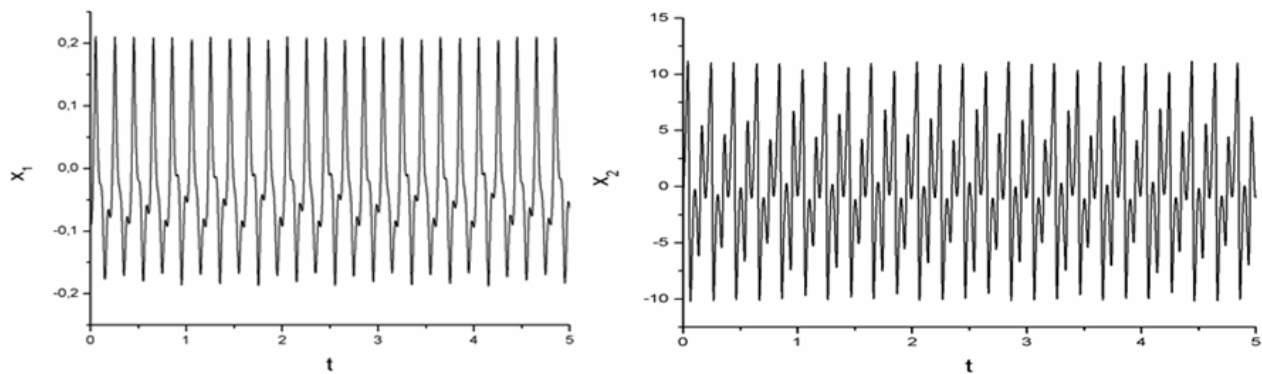


Figure 1 - Change in the time of movement and speed of the combined mass of the hydraulic hammer in steady state

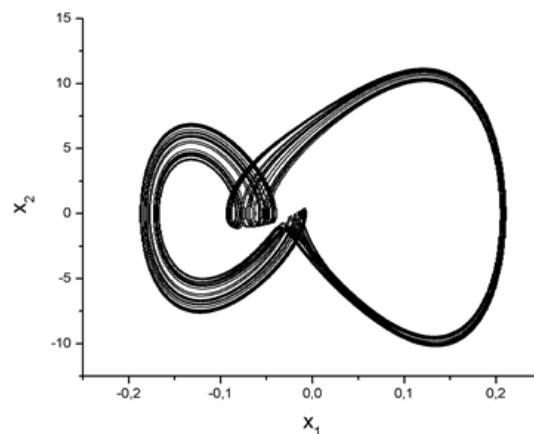


Figure 2 - Phase portrait of the system (2)

Results. As can be seen from Fig. 2, the oscillations in system (2) are not exactly periodic. To clarify their character, Fourier series of curves were obtained. The spectra for both variables are shown in Fig. 3. Amplitudes of the harmonics of Fourier decomposition of functions are denoted by A_1 and A_2 , respectively; f - frequency. On the basis of fig. 3 we can conclude that the curves given can be attributed to almost periodic type [4], since the frequencies of some higher harmonics are not multiples of the main component of the spectrum - 5 Hz.

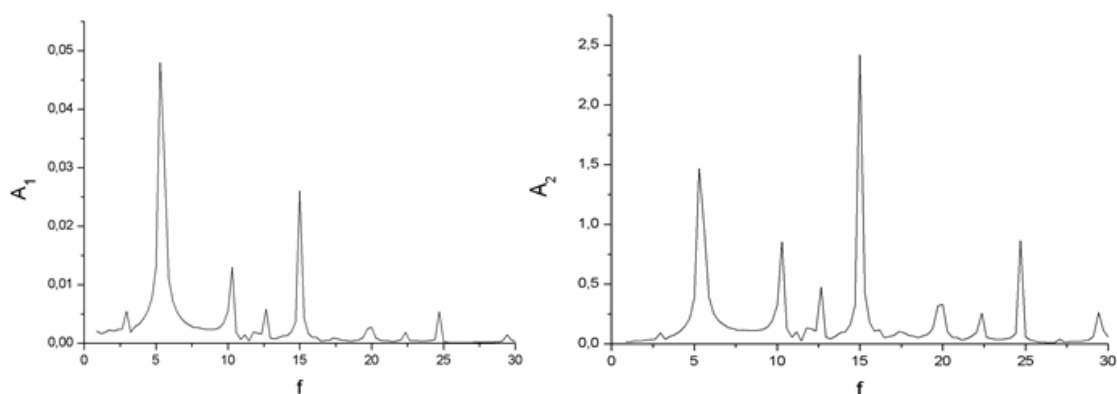


Figure 3 - Function spectra $x_1(t)$ and $x_2(t)$

A study was performed to identify possible changes in the modes of operation of the simulated device depending on the dissipation coefficient b . Its magnitude varied within 800...10. It was found that, with the greatest damping from the given range ($b = 800$), the model operates in

the periodic oscillation mode. It is illustrated by phase portrait in Fig. 4. The frequency of these oscillations coincides with the frequency of external action.

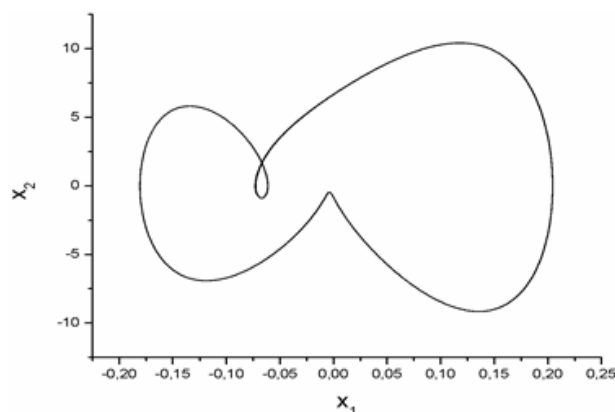


Figure 4 - Phase portrait of system (2) at $b = 800$

With further decrease in the dissipation coefficient, bifurcation of doubling of the period is observed [5]. This phenomenon is illustrated in Fig. 5.

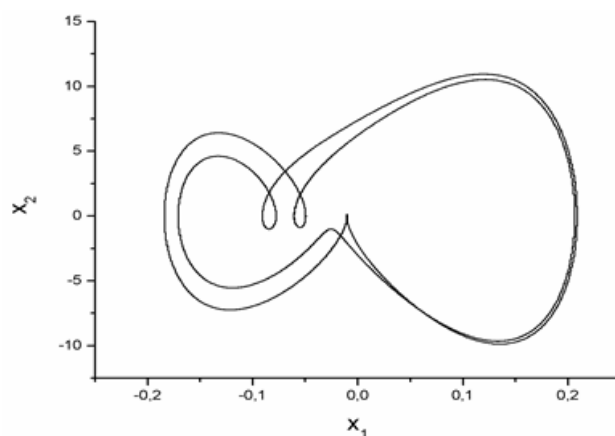


Figure 5 - Phase portrait of system (2) at $b = 585$

When reaching the values of $b < 450$ the curves acquire features of chaotic mode [5]. This is evidenced by the appearance of functions $x_1(t)$ та $x_2(t)$, Fig. 6. Such dynamics of the system persists throughout the lower part of the range of change of the studied parameter, i.e. up to $b = 10$.

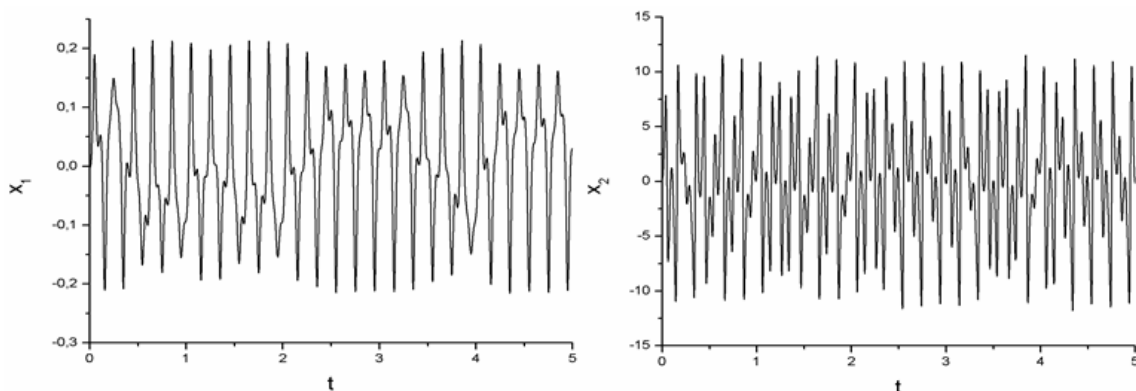


Figure 6 - The change in the time of movement and speed of the combined mass of the hydraulic hammer in the steady state at $b = 300$



The effect of mass change on the operation of the hydraulic system was also investigated. It turned out that in the range of mass changes from 10 to 100 (other parameters remained unchanged), the system operates mainly in the periodic mode. More detailed approximate ranges of modes are shown in table 1.

Table 1 - Changing modes of the hydraulic system when changing mass

The range of m	10-55	55-70	70-90	90-100
Mode	Periodic	Almost periodic	Doubling of period	Periodic

Conclusions. The study revealed the dependence of the modes of operation of the hammer on the values of the parameters of its mathematical model. It is revealed that at nominal parameters the hydro-impulse system operates in almost-periodic mode. When the dissipation coefficient increases, the dynamics of the device is periodic, when the frequency of oscillations in the system coincides with the frequency of external action. When the coefficient of dissipation is reduced, bifurcation of the doubling of the period is observed. Also, an important feature of this system is the possibility of a mode of deterministic chaos at certain values of the coefficient of dissipation. As the study showed, when the value of the consolidated mass changes, the system operates in periodic mode or in double period mode, or it operates in almost periodic mode. The above mentioned characteristics of the model can be useful for the design of hydro-pulse systems and for the choice of modes of their operation.

References

1. Сліденко В.М. Адаптивне функціонування імпульсних виконавчих органів гірничих машин / В.М. Сліденко, С.П. Шевчук, О.В. Замараєва, Л.К. Лістовщик. – К., 2013. – 180 с.
2. Сліденко В.М. Математичне моделювання ударно-хвильових процесів гідроімпульсних систем гірничих машин / В.М. Сліденко, О.М. Сліденко. – К., 2017. – 220 с.
3. Быховский И.И. Основы конструирования вибробезопасных ручных машин / И.И. Быховский, Гольдштейн Б.Г. – М., 1982. – 224 с.
4. Levitan B.M. Almost-periodic functions / B.M. Levitan. - M., 1953. – 396 p.
5. Loskutov A.Yu. Introduction to Synergetics / A.Yu. Loskutov, A.S. Mikhailov. - M., 1990. – 272 p.

УДК 338.45: 330.341.1: 691.42

Shevchuk N.A.
PhD, Assoc. Prof.,
Igor Sikorsky Kyiv Polytechnic Institute
Sorochina S.D.
TUM,
The Department of Electrical Communications,
Chisinau, Republic of Moldova,

ECONOMIC EVALUATION OF IMPLEMENTATION ENERGY-SAVING TECHNOLOGIES ON THE ENTERPRISES FROM PRODUCTION CERAMIC BRICK

Annotation. Considered the recommendations of economic evaluation of the implementation of energy-saving technologies in brick factories. The process of ceramic brick production requires considerable energy and raw material resources and is quite energy intensive.